Nature-Inspired Cooling System Using Silicone Prototype: Modelling and Experimental Validation

Bharti, Palash (School: Jayshree Periwal International School)

The increase in thermal load due to AI infrastructure has led to a rise in power and water consumption. Evaporative cooling towers have low operational costs, but waste sizeable amounts of water. Conversely, closed-loop cooling reduces water waste, but has high energy costs. With reference to cooling methods involving shark skin and plant root geometry, I hypothesised that a cooling system inspired by natural geometry would reduce both the power and water use. A comparative study of the thermal resistance of shark fin, plant root, fennec fox ear, and elephant ear geometry predicted that the elephant ear geometry maximised resistance at constant heat flux, therefore maximising the temperature difference. The prediction was tested by modelling all four geometries using CAD and running simulations in ANSYS Fluent. A baseline test (velocity: 2 m/s, inlet temperature: 333 K, ambient temperature: 300 K, convection coefficient: 5 W/m²K) and a parametric analysis (velocity: 0.2 m/s, inlet temperature: 338 K, ambient temperature: 323 K, convection coefficient: 50 W/m²K and 300 W/m²K) were conducted. Both tests predicted a maximum temperature drop in the elephant ear geometry, with 1.4 °C at the baseline and 3.9 °C with the velocity parameter varied. A silicone prototype of the elephant ear geometry was created and integrated with a closed-loop system. A PTC Heater was connected to an aluminium chamber to simulate the heat of the server racks. Over a period of 300 s, the silicone prototype showed a maximum temperature drop of 12.7 °C at 3.7 W/sq. ft. The heat exchanged by the system was 10.8 times the operating power, with an overall system efficiency of 64.5%. The prototype exhibited a 93% reduction in power use and eliminated evaporative water waste, validating the hypothesis.

Awards Won: